

IN THE SPECIFICATION

Please replace the paragraph beginning at page 1, line 11, with the following replacement paragraph:

Q<sup>1</sup> The present application is related to U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~ Serial No. 09/680,708 entitled "Method and Apparatus for Providing Channel Error Protection for a Source Coded Bit Stream," filed concurrently herewith in the name of inventors R. Anand, H.-L. Lou and C. Podilchuk, and incorporated by reference herein.

Please replace the paragraph beginning at page 1, line 21, with the following replacement paragraph:

Q<sup>2</sup> In conventional communication systems, a coded video bit stream may be transmitted over a heterogeneous wired-to-wireless network. For example, the coded video bit stream may be transmitted from a wired Internet connection to a wireless mobile receiver. Due to differences in loss conditions and bandwidth constraints between the wired and wireless portions of the network, it is common in such coded video bit stream transmissions to partially or fully decode the coded video bit stream, reencode the video at an appropriate rate, and then add error resiliency properties prior to transmission to the wireless receiver. An example of a technique of this type is described in G. de los Reyes et al., "Video Transmission For Resilience in Wireless Channels," IEEE International Conference on Image Processing, Chicago, IL, pp. 338-342, October 1998.

Please replace the paragraph beginning at page 3, line 3, with the following replacement paragraph:

Q<sup>3</sup> Known video transmission techniques for lossy channel conditions have focused on either adding error resilient features to well-defined coding standards such as H.263++ and MPEG-4, or on channel coding for either packet losses over Internet protocol (IP) connections or wireless channel conditions. Examples of the former types of techniques are described in J. Wen et al., "A Class of

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Reversible Variable Length Codes For Robust Image and Video Coding," Proceedings of the IEEE International Conference on Image Processing, Santa Barbara, CA, Vol. 2, pp. 65-68, October 1997; J. Villasenor et al., "Robust Video Coding Algorithms and Systems," Proceedings of the IEEE, Special Issue on ~~Wireless Video~~, Video Transmission For Mobile Multimedia Applications, Vol. 87, No. 10, pp. 1724-1733, October 1999; and N. Farber Fäber et al., "Extensions of ITU-T Recommendation H.324 For Error-Resilient Video Transmission," IEEE Communications Magazine, pp. 120-128, June 1998, while examples of the latter types of techniques are described in C. Leicher, "Hierarchical Encoding of MPEG Sequences Using Priority Encoding Transmission (PET)," Berkeley Technical Report TR-94-058, November 1994; B. Girod et al., "Packet Loss Resilient Internet Video Streaming," Visual Communications and Image Processing '99, SPIE, San Jose, CA, January 1999; A.E. Mohr et al., "Graceful Degradation Over Packet Erasure Channels Through Forward Error Correction," Proceedings of the 1999 Data Compression Conference (DCC), Snowbird, Utah, pp. 1-10, 1999; K.W. Stuhlmüller et al., "Scalable Internet Video Streaming With Unequal Error Protection," Packet Video Workshop, New York, pp. 1-8, April 1999; R. Puri et al., "Multiple Description Source Coding Using Forward Error Correction (FEC) Codes," 33<sup>rd</sup> ASILOMAR Conference on Signals, Systems, and Computers, Pacific Grove, CA, IEEE, pp. 342-346, 1999; B. Girod et al., "Feedback-Based Error Control for Mobile Video Transmission," Proceedings of the IEEE, Special Issue on Video Transmission For Mobile Multimedia, Multimedia Applications, ~~accepted for publication~~, Vol. 87, No. 10, pp. 1707-1723, October 1999; and P.G. Sherwood et al., "Error Protection For Progressive Image Transmission Over Memoryless and Fading Channels," IEEE Transactions on Communications, Vol. 46, No. 12, pp. 1555-1559, December 1998.

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Please replace the paragraph beginning at page 4, line 2, with the following replacement paragraph:

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The present invention provides methods and apparatus for video transmission over a heterogeneous network which meet the above-described need by generating a progressive coded video bit stream configured so as to be decodable at any one of a series of increasing bit rates up to

Q4 a maximum bit rate, depending on which of a number of corresponding portions of the progressive coded video bit stream are received by a decoder. Each of the portions is associated with a different bit rate, and one or more of the portions may each also be associated with different values of other coding-related parameters such as frame rate, spatial resolution, and peak signal-to-noise ratio. Each of the series of increasing bit rates produces progressively better reconstructed video signal quality at an output of the decoder. The progressive coded bit stream is transmitted over a first part of a heterogeneous network at a first one of the bit rates. One or more selected portions of the progressive coded video bit stream are then transmitted from the first part of the heterogeneous network to a second part of the heterogeneous network. The selected portions are associated with a second one of the bit rates lower than the first bit rate, and may be selected based on an error detected in the transmission over the first part of the heterogeneous network, a characteristic of the second part of the heterogeneous network, or combinations of these and other factors.

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Please replace the paragraph beginning at page 5, line 21, with the following replacement paragraph:

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Q5 In operation, a source video signal is applied to the progressive video coder 110. The source video signal may comprise, e.g., a sequence of frames. The progressive video coder 110 generates a progressive coded video bit stream in a manner to be described in greater detail below in conjunction with FIGS. 2 and 3. The progressive coded video bit stream is then applied to the channel coder 112, which applies unequal error protection channel coding to the progressive source coded bit stream using the progressive channel coding techniques described in the above-cited U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~ Serial No. 09/680,708. It should be noted, however, that other channel coding techniques could also be used.

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Please replace the paragraph beginning at page 6, line 27, with the following replacement paragraph:

Q6 More particularly, the maximum target bit rate  $R(4)$ , which is achieved when all five portions of the bit stream 200 are received, corresponds to a 30 frame per second (fps) video signal having a ~~CIF~~ common intermediate format (CIF) resolution of 360x240 pixels. The bit stream 200 scales down from right to left in terms of frame rate, from 30 fps if all five portions are received, to 15 fps if the first four are received, and subsequently to 10 fps if only the first three or fewer portions are received. Similarly, the bit stream scales down from right to left in resolution from the CIF resolution if at least the first three portions are received, to a quarter-CIF (QCIF) resolution of 180x120 pixels if only the first two or fewer portions are received. The bit stream 200 also scales downward from right to left in peak signal-to-noise ratio (PSNR), from a maximum value  $PSNR(4)$  through intermediate values  $PSNR(3)$ ,  $PSNR(2)$ ,  $PSNR(1)$  and  $PSNR(0)$  depending on the portions received, and in bit rate, from the above-noted maximum target bit rate  $R(4)$  through intermediate values  $R(3)$ ,  $R(2)$ ,  $R(1)$  and  $R(0)$ , again depending on the portions received.

Please replace the paragraph beginning at page 7, line 10, with the following replacement paragraph:

Q7 As mentioned previously, a fully-embedded progressive coded video bit stream such as that shown in FIG. 2 can be provided with unequal channel error protection in the manner described in the above-cited U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~ Serial No. 09/680,708. Such an arrangement allows for efficient adaptation of the bit stream across heterogeneous networks, with low complexity and optimum bandwidth utilization. More particularly, a progressive coded video bit stream of the type described above can be utilized in the illustrative embodiment of the invention to provide direct bit rate adaptability at the bit stream level, such that an encoded video sequence can adapt to any bit rate available across a given heterogeneous wired-to-wireless network.

Please replace the paragraph beginning at page 8, line 16, with the following replacement paragraph:

Q<sup>8</sup> The present invention can be implemented using a conventional progressive video coder. For example, a so-called SPIHT Set Partitioning in Hierarchical Trees (SPIHT) coder may be used to implement the progressive video coding described above. Additional details regarding conventional SPIHT coders are described in, e.g., A. Said et al., "A New Fast and Efficient Image Codec Based on Set Partitioning in Hierarchical Trees," IEEE Transactions on Circuits and Systems for Video Technology, Vol.6, June 1996; B.-J. Kim et al., "Very Low Bit-Rate Embedded Video Coding with 3D Set Partitioning in Hierarchical ~~Trees~~, Trees (3D SPIHT)," IEEE Transactions on Circuits and Systems for Video Technology, Special Issue on Image and Video Processing for Emerging Interactive Multimedia Services, Sept. 1998; and B.-J. Kim et al., "Low-Delay Embedded 3D Wavelet Color Video Coding with SPIHT," Proc. SPIE, Visual Communications and Image Processing '98, pp. 955-964, Jan. 1998; all of which are incorporated by reference herein.

Please replace the paragraph beginning at page 9, line 17, with the following replacement paragraph:

Q<sup>9</sup> Although the channel error protection for the progressive bit stream is preferably provided using the techniques described in the above-cited U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~, Serial No. 09/680,708, any of a wide variety of well-known conventional channel coding techniques may be used in conjunction with the invention, such as convolutional or Turbo codes, cyclic redundancy check (CRC) codes, or combinations of these and other codes. For example, rate compatible puncturing of convolutional or Turbo codes may be used to provide unequal error protection for the progressive bit stream. Such channel coding techniques are known in the art and therefore not described in detail herein.

Please replace the paragraph beginning at page 10, line 8, with the following replacement paragraph:

Q<sup>10</sup> As mentioned previously, channel error protection techniques suitable for use in conjunction with the present invention are disclosed in U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~ Serial No. 09/680,708.

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Please replace the paragraph beginning at page 11, line 10, with the following replacement paragraph:

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Q<sup>11</sup> In operation, the progressive video bit stream 300 of FIG. 3 is generated by the progressive video coder 110. The channel coder 112 provides progressive channel error protection for the progressive source coded bit stream in the manner described in the above-cited U.S. Patent Application ~~Attorney Docket No. Anand 1-16-15~~ Serial No. 09/680,708. The resulting channel coded output is delivered via transmission medium 106 to the mobile receiver 104' where it is processed to recover the original video stream.

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